ISSN NO. 2320-5407

*Journal homepage: http://www.journalijar.com*

***INTERNATIONAL JOURNAL OF ADVANCED RESEARCH***

**RESEARCH ARTICLE**

# Community Structure of Zoobenthos in Some Freshwater Bodies in Taif, Saudi Arabia.

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## Manuscript Info

***Manuscript History:***

Received: 12 February 2014
Final Accepted: 22 March 2014
Published Online: April 2014

***Key words:***
Taif, macrobenthes, environmental variables, Saudi Arabia

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## Abstract

Saudi Arabia is one of the most arid countries in the Middle East and North Africa (MENA) region and its freshwater resources are rapidly changing which greatly influences the freshwater fauna. The present work aimed to investigate the faunal community of some freshwater bodies in Taif, Saudi Arabia and their response to some environmental variables. Five different sites were selected for the study. 32 taxa were recorded in the random samples collected from these sites 13 of them are dominant. The highest macrobenthos density in the present study was in site (I) followed by site (II) while, the minimum density was recorded in site (V). Sites (I & III) were heavily populated by *Chironomus* larvae which indicate their organic pollution from the sewage treatment planet. The highest species richness was recorded in site (II) followed by site (I) on the other hand; site (III) was the lowest value among the study sites. This may indicate the impact of pollution in this area from the poultry farm nearby. Species diversity showed the maximum value of Shannon Waever index in site (V) followed by site (II), while site (III) was the lowest diversity among the study sites.



## 1. Introduction:

Freshwater resources have a great importance all over the world especially the desert countries. Saudi Arabia is one of the most arid countries in the Middle East and North Africa region and its freshwater resources are rapidly depleting. Aquifers, a major source of water in Saudi Arabia, are vast underground reservoirs of water (Al-Ghanim, 2012 and Al-Zahrani and Baig, 2011).

Freshwater ecosystems and its diverse biological biota are among the most endangered in the world (Dudgeon et al., 2006) with eutrophication, acidification and hydromorphological alteration among the major anthropogenic stresses on water bodies (Halpern et al., 2008 and Solimini et al., 2006). Human activities are associated with many changes including the removal of the native organisms, and replacing them with different species of organisms that are able to cope with the introduced stresses (Moyle et al. 2010). In addition to the unfavorable effects of human activities, freshwater ecosystems also exposed to unpredictable climate change induced alterations expressed by an increased frequency and/or intensity of extreme weather events (e.g. floods and droughts) (Harley et al., 2006; Mitchell et al., 2006; Paerl, 2006; Bates et al., 2008).

Most of the freshwater in Taif, a city in the Mecca Province of Saudi Arabia comes from the fallen rains on Sarawat Mountains. There are four pathways for the flood water, Wadi Al-Arj, Wadi Al-Aqiq, Wadi Masarrah, Wadi Wakdan and Wadi Leyah (Taif Municipality project). Some parts of these streams are subjected to partially treated or completely untreated sewage discharge (Baeshen, 2008 and Bahabri, 2011). Similar findings were reported by Raza, (2004) who studied the municipal activities influencing the quality of the groundwater in the aquifer in wadi Al-Arj in Taif.

Biodiversity of freshwater ecosystem is the overriding conservation priority during the International Decade for Action ‘‘Water for Life’’ 2005 to 2015 (Dudgeon et al., 2006). Therefore, the assessment of biological diversity in freshwaters plays a crucial role as the basis for nature protection. Samaan (1977) pointed that macrobenthic fauna feed mostly on detritus and other smaller benthic organisms, converting them into flesh of their bodies. They in turn furnish a direct food for bigger aquatic animals including fish.

Ecological monitoring and the changes in macrobenthos community structure due to the changes of environmental parameters is a good way in understanding the changes in the aquatic ecosystem where their health, diversity and distribution are related environmental conditions and water quality (Satheeshkumar and Khan, 2013); they are also considered as biological indicator for the water quality due to their sedentary lifestyle (Urban-Malinga et al., 2014). This information is critically needed for conservation planning and understanding ecosystem processes (Curry et al., 2012).

There is a few work has been done on macrobenthos at different places in Saudi Arabia. Recently, few studies were performed on zoobenthos at Taif region (Abd El-Wakeil and Al-Thomali, 2013; Al-Thomali, 2013). They concentrated their study in macro-fauna in wadi Al-Arj. Therefore the present work aimed to investigate the geographical variation in zoobenthic macrofaunal community structure of some freshwater bodies in Taif, Saudi Arabia by evaluating some of its features; including benthic abundance, species richness and Shannon diversity of the studied communities and their response to some environmental variables.

## 2. Materials and Methods

### 2.1 Study area:

Sampling was carried out during the period from March 2012 to June 2013 at El-Taif city in the Mecca Province of Saudi Arabia 21°16′00″N 40°25′00″E at an elevation of 1,879 m on the slopes of Al-Sarawat Mountains, from which most of the freshwater in Taif comes. There are four pathways for the flood water, Wadi Al-Arj, Wadi Al-Aqiq, Wadi Masarrah, Wadi Wakdan and Wadi Leyah (Taif Municipality project). Macro-invertebrates were sampled from five sites in the flood routes mentioned above (Fig.1).

**Site I (Wadi Al-Arj):**

Wadi Al-Arj is the downstream section of Wadi Wajj that flows from Southwest to Northeast through Taif city. Along the Wadi and its banks there are several agricultural, grazing and municipal activities. There is also a wastewater treatment plant that pours the treated sewage in the course of the flood water. The regional vegetation structure in the course of the stream includes *Abutilon pannosum*, *Cassia italica*, *Mentha longifolia*, *Xanthium strumarium*, *Tamarix nilotica*, *Calotropis procera*, *Solanum incanum*, *Datura innoxia*, *Lycium shawii*, *Acacia laeta*, *Acacia ehrenbergiana* and *Typha domingensis*. The stream consists mainly of sand derived by the water current; its water is shallow, always running, and almost clear. Four sampling sites were chosen along Wadi Al-Arj downstream.

**Site II (Sayisd):**

This site is close to saysid national park, which is the upstream section of Wadi Al-Arj. It is located at 9 Km in the northeast of Taif city at 1580 m above the sea level. It receives the flood water from Sarawat Mountain, its bottom is mostly rocky covered by sand and gravels derived by the water current that is always running. The regional vegetation structure on the stream bank consists of *Typha domingensis*, *Cynodon dactylon*, *Ricinus communis*, *Mentha longifolia*, *Xanthium strumarium*, *Tamarix nilotica*, *Calotropis procera*, *Solanum incanum*, *Datura innoxia*, *Acacia laeta*, *Acacia ehrenbergiana*, *Coronopus didymus*, *Pluchea dioscroides* and *Chrozophora oblongifolia*. This stream is subjected to light human activities, which may influence the biotic diversity in the area. Three sampling sites were chosen along sayisd stream.

**Site III (Wetland):**

This site is a wide area, about 1000 $m^2$, of closed water on the side of the new road to Romaydah close to Wadi Al-Arj downstream. It has heavy vegetation structure that consists of emergent plants such as *Typha* *domingensis*, *Acacia laeta*, *Acacia gerrardii* and *Tamarix nilotica* and number of submerged plants. The water is stagnant and green in color, its depth ranges from 0.3 to 1.5 m. The bottom is rocky; its water is permanent throughout the year, with slight seasonal variations in its quantity. Three sampling sites were chosen along the wetland area. The first is in the area covered by heavy vegetation and characterized by dark water and high humus in the bottom. The second is in the area covered by short emergent plants and submerged plants. The third is in the exposed shallow area, there is no vegetation in this part.

**Site IV (Jabajeb pond):**

This pond, about 500 $m^2$, is located along Al-Hada road. Its water is stagnant, slightly turbid and green in color. Its regional vegetation structure consists of *lemna gibba* that is distributed in a clumped pattern on the water surface; some submerged plants, such as *Ceratophyllum demercium*, appear during dry season; some plants such as *Acacia gerrardii*, *Tamarix nilotic* and *Rumex vesicarius* grow on the banks. The bottom is rocky covered with some mud and sand derived by the flood water from the neighboring mountains. Two sampling sites were chosen along Jabajeb pond.

**Site V (Ghadeer Al-Banat):**

Ghadeer Al-Banat is located at 9 km southeast of Taif city. It is a wide stream that receives the rain water from Sarawat and Shafa Sofian Montains through Wadi Leyah. It is about 1700 m above the sea level. The water is slightly turbid and almost present all over the year. Its vegetation structure contains algae and *Lemna gibba* clumped on wide areas of the water surface in addition to the submerged plant *Ceratophyllum demercium*. The bottom is mainly rocky with some sand and mud. Its water is mostly stagnant, with the exception of the flood time. The stream site is exposed to limited camping activities. Three sampling sites were chosen along Ghadeer Al-Banat.

**2.2. Collection and identification:**

At each sample site, pH, water temperature, and total dissolved salts (TDS) were recorded. In addition, water samples were taken for laboratory analysis of each of the following chemical variables: ammonia, nitrate, nitrite and phosphate. Samples of sediment were taken for measuring organic matter content. The macro-invertebrates were collected quantitatively and randomly with D-net towed for 1 meter, three replicates were taken from each location. All samples were washed and cleaned samples were placed in a labeled plastic container and fixed with 5% formaldehyde solution. In the laboratory, animals were separated using a stereomicroscope, and then organisms were identified to family, genus or species level when possible. The following identification keys were used: Brown (1980), Habashy (1993), El-Shimy (1994) and Ibrahim et al. (1999). Macrobenthic organisms were separated and counted for each collected sample.

**2.3 Samples treatment:**

The dominance structure of Gamasina species was determined according to Engelmann's classification (Engelmann, 1978) as subrecedent (bellow 1.3%), recedent (1.3-3.9%), subdominant (4-12.4%), dominant (12.5-39.9%), eudominant (40-100%). Shannon wiener diversity index (H`) was calculated to show the invertebrates diversity within the collected communities by using shannon-wiener equation:
H` = $-\sum pi (\ln pi)$, where **pi** is the proportion of individuals belonging to the $i^{th}$ species. Invertebrates' richness of these communities was calculated.

**2.4 Statistical analysis:**

Analysis of Variance on SPSS software package (version 17) (SYSTAT statistical program) was used to test the present data. Duncan test was used to detect the distinct variances between means. The program Canoco for windows 4.5 was used for canonical corresponded analysis (CCA) as a unimodal method to analyze the response of the benthic community composition to environmental variables.

## 3 Results:

Present results indicated clear geographical differences among study sites in the detected water environmental variables (Table 1). Water pH was in the alkaline range, with the highest pH value in site IV that was significantly higher than the other four study sites. The highest TDS, Ca and phosphate concentrations were recorded in site III with significant differences when compared to all other study sites in case of TDS and Ca levels, such significant increase was not proved for phosphate concentration when compared to site IV. Concentrations of ammonia in site V, nitrates and nitrites in site II showed significant higher level when compared to all other study sites. Organic matter level in the sediments of sites I and II showed significant higher levels when compared to the other three study sites.

A total of 32 macrobenthos taxa were collected, 13 of them are dominant and one taxon (*Chironomus* larva) is eudominant (Table 2). The recorded taxa belong to 10 benthic groups (Hemiptera, Diptera, Odonata, Ephemeroptera, Coleoptera, Lepidoptera, Crustacea, Gastropoda, Annelida and Platyhelminthes). 29 of these taxa were collected by quantitative sampling from the study sites. The number of taxa varies among the five sites, 19, 12, 6, 6 and 10 taxa were collected from sites I, II, III, IV and V respectively. Four taxa (*Ambrysus* sp, *Limnophora riparia*, Mayfly larva, *Stenocypris* and *Planaria*) were exclusive for Site I, meanwhile three taxa, (*Libellula* nymph *Libellula forensis* nymph and *Melanoides tuberculata*) were exclusive only for site II, two taxons (*C. fimbriolatus* larva and *Psychodidae* larva) were exclusive for site IV and two taxa (*Chirocephalus* and *Triops*) were exclusive for site V. On the other hand no taxa were exclusive for site III (Table 3).

*Chironomus* larva presented the highest density in site III with 3609.0 individuals/m$^2$ being collected; *M. tuberculata* presented the highest density in site II with 128.7 individuals/m$^2$ *C. punctata* presented the highest density in site IV with 35 individuals/m$^2$ *Hyphydrus* larva presented the highest density in site V with 26 individuals/m$^2$.

The ANOVA test showed that the macro-invertebrate fauna composition varied significantly among the five study sites (Table 4). Hemiptera and Diptera showed their highest densities in site III that were significantly higher when compared to site I and IV for Hemiptera and to site II, IV and V for Diptera. Odonata, and Gastropode displayed their highest densities in site II and in site IV for Coleoptera that were significantly higher than other study sites. Meanwhile, Annelida showed its highest density in site I. Crustacea was represented in site I by ostracodes and in site V by *Triops* sp and the fairy shrimp *Cherocephalus*.

Data analysis revealed significant geographical differences in both total abundance (F= 2.779, p=0.051) and Shannon diversity index (F= 2.711, p=0.055). Site III showed the highest recorded value for the total abundance of macrobenthos that was significantly higher when compared to the relevant values of site II, IV and V. Species diversity in site III showed a significant lower value of Shannon index if compared to the relevant values of site II, IV and V. However, species richness showed no significant geographical differences between the different study sites; anyhow site III indicated the lowest species richness in comparison to the other four study sites (Fig. 3). Present results indicated different similarity distances between the different study sites. Sites I and III were separated from the other sites. Sites IV and V were similar to each other followed by site II (Fig. 4).

The results of canonical correspondence analysis (CCA) ordination was performed on the recorded twenty nine benthos taxa and the corresponding studied environmental variables (water temperature, pH, TDS, sediment organic matter and Water Ca, Mg, $PO_4$, $NH_4$, $NO_3$, $NO_2$) for the collected samples from the investigated sites. Diagram of canonical correspondence analyses are shown in Fig. 5. The first two CCA axes together account for approximately 44.2% of the relations between invertebrates and environmental data. The results of CCA reveal that invertebrate composition mostly related to nitrite (NO2)_followed by water pH, Nitrate (NO3)_and phosphorus; while the rest of the studied environmental variables has relatively small effects in benthic invertebrates, especially sediment organic matter. Water temperature, pH, sediment organic matter and Water $NH_4$, $NO_3$, $NO_2$ show positive correlation with first canonical axis, while water TDS, Ca, Mg and $PO_4$, indicated negative correlation.

Table 1. Mean ± standard deviation (SD) of investigated environmental variables at study sites and statistical results (The similar characters for each factor show no significant difference).

| Environmental variables | | Site I | Site II | Site III | Site IV | Site V | F | P value |
|---|---|---|---|---|---|---|---|---|
| **Water Temp.** | Mean | 22.15 | 23.83 | 26.48 | 25.95 | 31.08 | 1.659 | 0.194 |
| | ± | ± | ± | ± | ± | ± | | |
| | SD | 4.62 | 1.17 | 2.03 | 0.44 | 13.14 | | |
| **pH** | Mean | 7.57 | 8.22 | 7.93 | 8.60 | 7.37 | 19.519 | 0.000 |
| | ± | ± | ± | ± | ± | ± | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | SD | 0.11 **a** | 0.15 **b** | 0.56 **b** | 0.08 **c** | 0.27 **a** | | |
| **TDS (ppm)** | Mean | 520.83 | 598.83 | 1277.25 | 295.25 | 171.00 | 28.261 | 0.000 |
| | ± | ± | ± | ± | ± | ± | | |
| | SD | 31.48 **b** | 53.47 **b** | 462.18 **c** | 4.27 **a** | 2.19 **a** | | |
| **Org.M. ( % )** | Mean | 11.69 | 11.13 | 6.52 | 5.33 | 6.93 | 17.317 | 0.000 |
| | ± | ± | ± | ± | ± | ± | | |
| | SD | 2 **b** | 2.42 **b** | 1.07 **a** | 0.64 **a** | 0.39 **a** | | |
| **Ca (mg/l)** | Mean | 158.36 | 171.73 | 270.50 | 131.00 | 91.67 | 61.154 | 0.000 |
| | ± | ± | ± | ± | ± | ± | | |
| | SD | 28.74 **c** | 10.95 **c** | 17.99 **d** | 7.3 **b** | 4.63 **a** | | |
| **Mg (mg/l)** | Mean | 64.48 | 19.23 | 37.30 | 8.78 | 5.72 | 12.698 | 0.000 |
| | ± | ± | ± | ± | ± | ± | | |
| | SD | 30.69 **c** | 1.95 **ab** | 13.17 **b** | 0.25 **a** | 0.63 **a** | | |
| **$PO_4$ (mg/l)** | Mean | 0.31 | 0.27 | 0.54 | 0.14 | 0.45 | 5.643 | 0.003 |
| | ± | ± | ± | ± | ± | ± | | |
| | SD | 0.01 **ab** | 0.04 **ab** | 0.38 **c** | 0.03 **a** | 0.03 **bc** | | |
| **$NH_4$ (mg/l)** | Mean | 0.53 | 0.11 | 0.27 | 0.22 | 0.63 | 52.314 | 0.000 |
| | ± | ± | ± | ± | ± | ± | | |
| | SD | 0.09 **c** | 0.04 **a** | 0.05 **b** | 0.03 **b** | 0.09 **d** | | |
| **$NO_3$ (mg/l)** | Mean | 0.89 | 1.01 | 0.39 | 0.13 | 0.95 | 14.350 | 0.000 |
| | ± | ± | ± | ± | ± | ± | | |
| | SD | 0.27 **b** | 0.13 **b** | 0.29 **a** | 0.04 **a** | 0.24 **b** | | |
| **$NO_2$ (mg/l)** | Mean | 0.04 | 0.09 | 0.05 | 0.04 | 0.07 | 0.643 | 0.637 |
| | ± | ± | ± | ± | ± | ± | | |
| | SD | 0.01 | 0.12 | 0.04 | 0.00 | 0.00 | | |

Table 2. Zoobenthos taxa collected from study sites in Taif, KSA with their percentages of frequency and dominance.

| **Taxonomical group** | **Collected Taxa (Famliy/Genus/Species)** | **F%** | **Dominance** |
|---|---|---|---|
| **Hemiptera** | *Corixa punctata* (Illiger, 1807) | 26 | Dominant |
| | *Ambrysus* sp.(Stal, 1862) | 14 | Dominant |
| **Diptera** | *Chironomus* Meigen, 1803 larva | 77 | Eudominant |
| | *Chironomus* Meigen, 1803 pupa | 23 | Dominant |
| | Mosquito larva | 14 | Dominant |
| | Mosquito pupa | 6 | Subdominant |
| | *Dichaeta caudata* (Fallén, 1813) larva | 9 | Subdominant |
| | *Dichaeta caudata* (Fallen, 1813) pupa | 9 | Subdominant |
| | *Limnophora riparia* (Fallén, 1824) larva | 3 | Recedent |
| | *Limnophora riparia* (Fallén, 1824) pupa | 6 | Subdominant |
| **Odonata** | *Cordulegastrida*e (Tillyard, 1917) “Spiketails dragonflies nymph” | 14 | Dominant |
| | *Corduliidae* Kirby, 1890 “Emeralds dragonflies nymph” | 20 | Dominant |
| | *Libellula* Linnaeus, 1758 “Pond skimmers dragonflies nymph” | 3 | Recedent |

| | | | |
|---|---|---|---|
| | *Libellula forensis* Hagen, 1861 “Eight-spotted Skimmer dragonflies nymph” | 3 | Recedent |
| | *Protoneuridae* Tillyard, 1917 “Threadtails damselflies nymph” | 31 | Dominant |
| **Ephemeroptera** | Mayfly | 11 | Subdominant |
| **Coleoptera** | *Cybister fimbriolatus* (Say, 1823) | 3 | Recedent |
| | *Cybister fimbriolatus* (Say, 1823) larva | 9 | Subdominant |
| | *Hydaticus* sp. Leach, 1817 | 6 | Subdominant |
| | *Hyphydrus* sp. (Illiger, 1802) larva | 23 | Dominant |
| **Lepidoptera** | *Psychodidae* larva | 3 | Recedent |
| | *Psychodidae* pupa | 3 | Recedent |
| **Crustacea** | *Chirocephalus diaphanus* Prévost, 1820 “fairy shrimp” | 11 | Subdominant |
| | *Triops longicaudatus* (LeConte, 1846) “tadpole shrimp” | 11 | Subdominant |
| | *Stenocypris* Sars, 1889 | 11 | Subdominant |
| **Gastropoda** | *Melanoides tuberculata* (Müller, 1774) | 14 | Dominant |
| | *Pseudosuccinea columella* (Say, 1817) | 14 | Dominant |
| | *Physa acuta* (Draparnaud, 1805) | 34 | Dominant |
| | *Biomphalaria arabica* (Melvill & Ponsonby, 1896) | 29 | Dominant |
| **Annelida** | *Limnodrilus hoffmeisteri* Claparede, 1862 | 34 | Dominant |
| | *Limnatis nilotica* (Savigny, 1822) | 3 | Recedent |
| **Platyhelminthes** | *Planaria* sp. Müller, 1776 | 6 | Subdominant |

**Table 3.** The mean values of benthos density (Indv./m2) and relative abundance (%) of collected taxa from study sites.

| Collected Taxa | Site I | | Site II | | Site III | | Site IV | | Site V | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Indv/m$^2$ | % | Indv/m$^2$ | % | Indv/m$^2$ | % | Indv/m$^2$ | % | Indv/m$^2$ | % |
| *Corixa punctata* | --- | --- | --- | --- | 48.0 | 1.21 | 35.0 | 44.87 | 1.3 | 2.67 |
| *Ambrysus* sp. | 5.2 | 0.35 | --- | --- | --- | --- | --- | --- | --- | --- |
| *Chironomus* larva | 1006.2 | 68.30 | 30.7 | 13.53 | 3609.0 | 90.82 | 20.0 | 25.64 | 6.7 | 13.33 |
| *Chironomus* pupa | 150.0 | 10.18 | 0.0 | 0.00 | 219.0 | 5.51 | --- | --- | --- | --- |
| Mosquito larva | 0.3 | 0.02 | 10.7 | 4.71 | --- | --- | --- | --- | --- | --- |
| *Mosquito pupa* | 1.0 | 0.07 | --- | --- | --- | --- | --- | --- | --- | --- |
| *D. caudata* larva | 0.7 | 0.05 | --- | --- | 1.0 | 0.03 | --- | --- | --- | --- |
| *D. caudata* pupa | 9.0 | 0.61 | --- | --- | --- | --- | --- | --- | --- | --- |
| *L. riparia* larva | 1.0 | 0.07 | --- | --- | --- | --- | --- | --- | --- | --- |
| *L. riparia* pupa | 4.2 | 0.28 | --- | --- | --- | --- | --- | --- | --- | --- |
| *Cordulegastridae* nymph | 0.7 | 0.05 | 0.7 | 0.29 | --- | --- | 2.0 | 2.56 | --- | --- |
| *Corduliidae* nymph | 1.7 | 0.12 | 0.7 | 0.29 | --- | --- | --- | --- | 0.7 | 1.33 |
| *Libellula* nymph | --- | --- | 2.0 | 0.88 | --- | --- | --- | --- | --- | --- |
| *L. forensis* nymph | --- | --- | 0.7 | 0.29 | --- | --- | --- | --- | --- | --- |
| *Protoneuridae* nymph | 1.7 | 0.12 | 33.3 | 14.70 | --- | --- | --- | --- | 0.7 | 1.33 |
| Mayfly | 12.8 | 0.87 | 0.0 | 0.00 | --- | --- | --- | --- | --- | --- |
| *C. fimbriolatus* larva | --- | --- | --- | --- | --- | --- | 4.0 | 5.13 | --- | --- |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Hyphydrus* larva | --- | --- | 1.3 | 0.59 | --- | --- | --- | --- | 26.0 | 52.00 |
| *Psychodidae* larva | --- | --- | --- | --- | --- | --- | 1.0 | 1.28 | --- | --- |
| *Psychodidae* pupa | 0.3 | 0.02 | --- | --- | --- | --- | --- | --- | --- | --- |
| *Chirocephalus* sp. | --- | --- | --- | --- | --- | --- | --- | --- | 2.7 | 5.33 |
| *Triops longicaudatus* | --- | --- | --- | --- | --- | --- | --- | --- | 4.0 | 8.00 |
| *S. hislopi* | 105.9 | 7.19 | --- | --- | --- | --- | --- | --- | --- | --- |
| *M. tuberculata* | --- | --- | 128.7 | 56.76 | --- | --- | --- | --- | --- | --- |
| *P. columella* | 0.3 | 0.02 | 0.0 | 0.00 | --- | --- | --- | --- | 3.3 | 6.67 |
| *P.acuta* | 113.5 | 7.71 | 6.0 | 2.65 | 64.0 | 1.61 | --- | --- | --- | --- |
| *B. arabica* | --- | --- | 6.7 | 2.94 | --- | --- | 16.0 | 20.51 | 1.3 | 2.67 |
| *L. hoffmeisteri* | 57.3 | 3.89 | 5.3 | 2.35 | 33.0 | 0.83 | --- | --- | 3.3 | 6.67 |
| *Planaria* sp. | 1.0 | 0.07 | --- | --- | --- | --- | --- | --- | --- | --- |

**Table 4.** The mean values of densities for benthic groups at different study sites and statistical results (The similar characters show no significant difference).

| Benthic groups | | Site I | Site II | Site III | Site IV | Site V | F | P value |
|---|---|---|---|---|---|---|---|---|
| **Hemiptera** | Mean ± SD | 5.25 ± 11.09 **a** | 0.00 | 48.00 ± 58.79 **b** | 35.00 ± 36.86 **ab** | 1.33 ± 3.27 **a** | 3.420 | 0.025 |
| **Diptera** | Mean ± SD | 1172.50 ± 1748.41 **ab** | 41.33 ± 76.64 **a** | 2025.50 ± 2334.24 **b** | 20.00 ± 21.91 **a** | 6.67 ± 8.64 **a** | 2.442 | 0.076 |
| **Odonata** | Mean ± SD | 4.25 ± 9.82 **a** | 37.33 ± 38.75 **b** | 0.00 | 2.00 ± 2.31 **a** | 1.33 ± 3.27 a | 4.077 | 0.012 |
| **Ephemeroptera** | Mean ± SD | 12.88 ± 27.73 | 0.00 | 0.00 | 0.00 | 0.00 | 1.012 | 0.422 |
| **Coleoptera** | Mean ± SD | 0.00 | 1.33 ± 3.27 **a** | 0.00 | 4.00 ± 5.66 **a** | 26.00 ± 17.3 **b** | 10.392 | 0.000 |
| **Lepidoptera** | Mean ± SD | 0.38 ± 1.06 | 0.00 | 0.00 | 1.00 ± 2.00 | 0.00 | 0.976 | 0.440 |
| **Crustacea** | Mean ± SD | 105.88 ± 197.03 | 0.00 | 0.00 | 0.00 | 6.67 ± 10.93 | 1.303 | 0.297 |
| **Gastropoda** | Mean ± SD | 114.00 ± 176.22 | 141.33 ± 154.69 | 64.00 ± 98.03 | 16.00 ± 19.32 | 4.67 ± 6.41 | 1.294 | 0.301 |
| **Annelida** | Mean ± SD | 57.25 ± 122.54 | 5.33 ± 7.87 | 33.00 ± 66.00 | 0.00 | 3.33 ± 4.68 | 0.780 | 0.549 |
| **Platyhelminthes** | Mean ± SD | 1.00 ± 2.83 | 0.00 | 0.00 | 0.00 | 0.00 | 0.587 | 0.675 |


Fig. 1: Map showing the five study sites in Taif Governorate, Saudi Arabia.


Fig. 2. Photographs showing the different study sites. A,B: site I, C,D: site II, E,F: site III, G,H: site IV and I,J: site V.

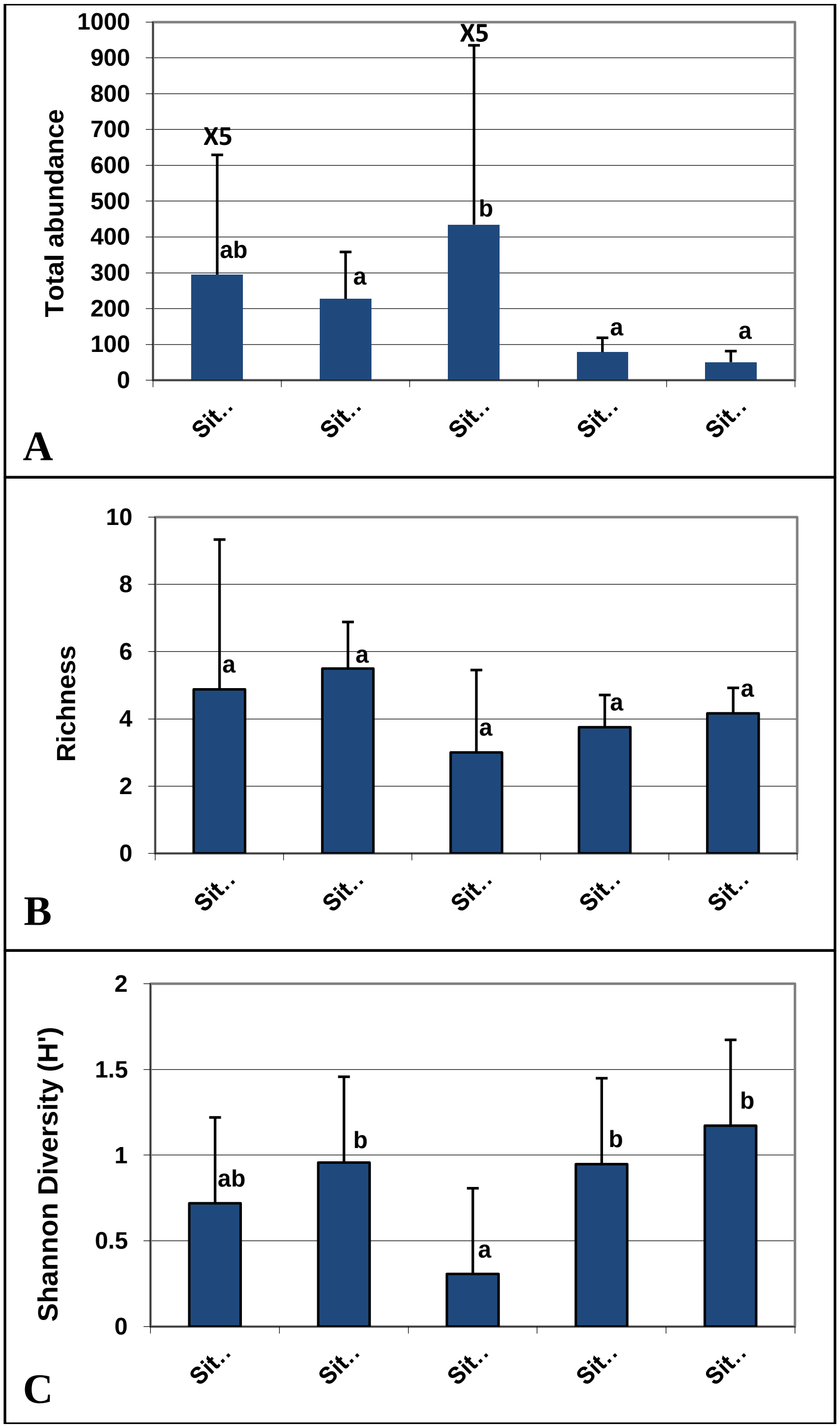


Fig. 3. The mean values of A: total benthic abundance, B: richness and C: Shannon diversity at study sites (The similar characters show no significant difference).

.

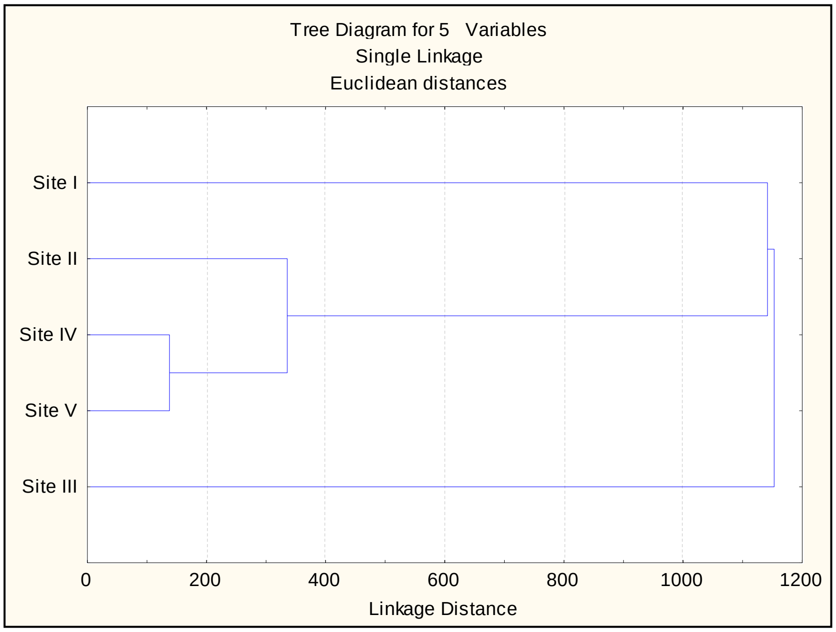


Fig. 4. Dendrogram showing the similarity distance between study sites using benthos density.

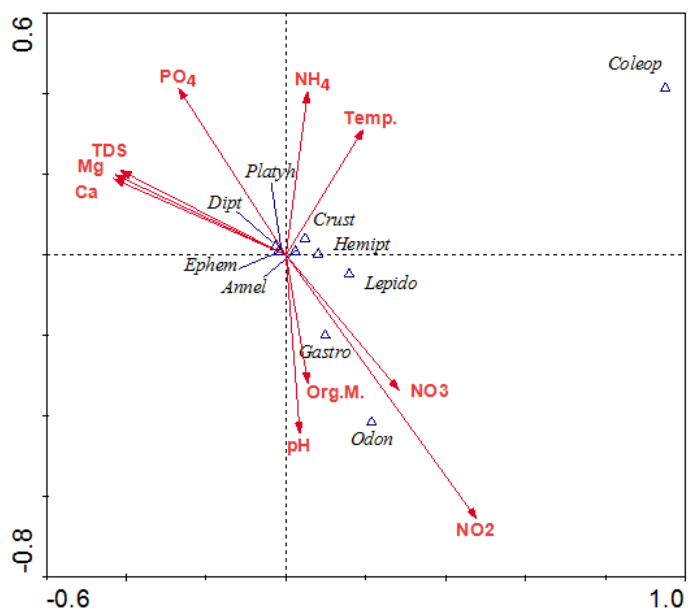


Fig. 5. Ordination bi-plot of the canonical correspondence analysis (CCA) with mean abundance of benthic fauna groups and different studied environmental variables. Benthic groups notation: Hemipt= Hemiptera, Dipt= Diptera, Odon= Odonata, Ephem= Ephemeroptera, Coleop= Coleoptera, Lepido= Lepidoptera, Crust= Crustacea, Gastro= Gastropoda, Annel= Annelida, Platyh= Platyhelminthes. Environmental factors notation: Temp.= water temperature, pH= water pH, TDS= Water dissolved salts, Org.M. = sediment organic matter and Water Ca, Mg, $PO_4$, $NH_4$, $NO_3$, $NO_2$.

## 4. Discussion

The results of the present study indicate the influences of ecological stresses on the communities. In studying structure of benthic invertebrate communities in karst systems, Smith et al. (2003) and Barquín and Death (2004) found, similarly, that flow variability may lead to significant spatial and temporal variability in aquatic community abundance and structure. In fact, increases of water current velocity and flow of the region under study might lead to the removal of benthic fauna through physical disturbance of the substrate (Flecker and Feifarek, 1994). This may explain the low abundance observed in site IV and site V. The relatively impoverished communities of these two study sites reflect the inability of many taxa to maintain populations in these sites due to the instability of these habitats where there are sever changes in the water level that may reach dryness. The absence of studies in Saudi streams avoids direct comparison of our results with other studies. Therefore, understanding how this dynamic environment works will only be possible with further studies. Food availability and shelter could have been more available in site III because of its high vegetation structure and consequently the availability of leaf litter, potential food and substrate for the macro-invertebrates may explain the higher abundance observed in the study site similar explanation was given by (Crisci-Bispo et al., 2007 and Wantzen et al., 2002) in their studies to explain seasonal variation macro-invertebrate community structure in dry and wet periods. The high abundance of organisms observed in site I and III in comparison to the other three study sites may also be related to the reduced availability of habitat area and the consequent increase in individuals' aggregation (Dudgeon, 1997; Diniz-Filho et al., 1998; Bispo et al., 2004).

Nutrient salts were measured in the water to indicate the trophic state of the water body. Muller and Helsel (1999) have categorized trophic status according to phosphorus concentration. According to this categorization the five studied streams are eutrophic since they all have phosphorus concentrations exceeding 0.020 mg/L. Phosphat concentration can affect periphyton productivity, and thus food availability. Different concentrations of ammonia, observed in the current study, could imply differing levels of toxicity (Arthur et al., 1987). However phosphorus levels were highest and ammonia levels were relatively low in site III, where macroi-nvertebrates were richer and this is expected to be as periphyton productivity was higher and toxicity was lower in this study region. The increase of the organic matter in site I could be explained by the increase density of *Chironomus* larvae that increase oxygen availability and enhance the depth over which oxidative organic decomposition occurs; as they live in u-shape tubes in the sediment at 5-20 cm (Pelegri and Blackburn, 1996). The observed variation in TDS could be due to the different evaporation rate induced because of the different topography of the studied streams. The increased organic matter content observed in site I could be explained by the sewage discharge in Wadi Al-Arj downstream.

In the current study, the highest density was recorded for *Chironomus* larvae; this was in agreement with Rabeni and Wang, 2001 who found Chironomidae as the most numerically dominant component of the benthos. Furthermore, dominance of *Chironomus* larvae in sites III and I reflects the organic pollution of the water. Additionally, Abd-El-Wakeil and Al-Thomali (2013) found the hemiptran species, *Anisopus deanei* but in the present work *Corixa punctata* was recorded. This means that both species are existing and this is attributed to the method and time of collection. Mayfly larva, family Leptophlebiidae was one of the four taxa detected for being exclusive for Site I. This could be explained by Armitage et al., 1983 who associated the occurrence of Mayfly family Leptophlebiidae with fast-flowing clean waters. The low abundance of crustaceans and absence molluscs observed in the current study is noticeable; as such organisms are generally preferred by high alkalinity (Giller and Twomey, 1993; Wright et al., 2003). A possible reason for the observed low abundance might be the unstable hydraulic conditions exhibited by the studied streams.

The present study shows geographical variation in the composition of macro-invertebrate fauna among the five study sites. Koperski (2010, 2011), in his study on lowland streams, clarified that taxonomic diversity of the main groups of macrobenthos is affected by different environmental parameters: Ephemeroptera, that was detected for being exclusive for Site I, is affected by stream pollution; Gastropoda, that presented their highest densities in site II, is affected by the type of bottom substrate. The taxonomic richness of Ephmeroptera which is one of the so called EPT group (Ephmeroptera, Plecoptera, and Trichoptera combined) was proved to be sensitive to oxygen concentration and so it is commonly used in biological assessment as a metric of stream pollution (Growns et al., 1997) and also as a parameter responding along gradients of land-use and riparian cover (Moore and Palmer, 2005).

The present work is a preliminary description of the macro-invertebrate communities of selected Saudi Arabian streams in Taif city. This type of environment as well as this region has been very poorly studied to date.

These data should provide a basis for future studies, leading to a better understanding of the structure of these aquatic communities. Although the current study present some evidences about the influence of environmental variables on the benthic community structure, these influences seem to be questionable, weak, and unclear. Different studies on the effects of decreased pH yielded opposite conclusions (Sandin 2003; Petchey et al. 2004; Petrin et al. 2007). Likewise Johnson and Hering (2009) noted that diversity of macrobenthos was not a significant predictor of nutrient enrichment or habitat degradation. Better explanation of the observed variation in the benthic community structure could be the stream diversity in floral assemblages and hence variation in habitat complexity and other environmental variables may be able to support a more varied invertebrate fauna (Metzeling and Miller, 2001).

## Acknowledgments

This work was supported by a grant (contact No. 2775-434-1) sponsored by Taif university, Saudi Arabia.

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